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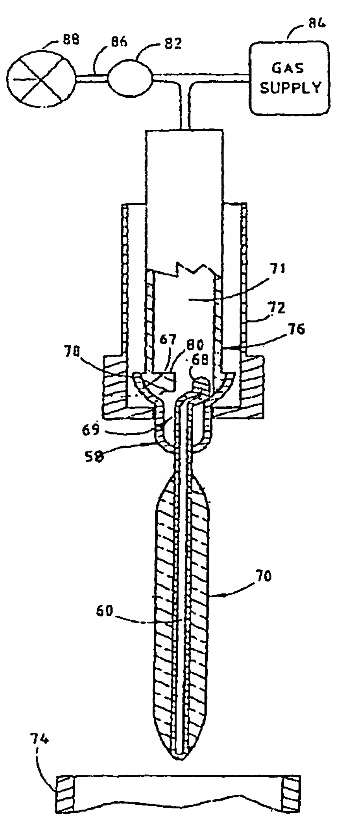
(54) Title: METHOD OF MANUFACTURING AN OPTICAL FIBER FROM A PERFORM AND OPTICAL FIBER MADE BY THE METHOD



(57) Abstract: A method of manufacturing a glass article, such as an optical fiber. The method comprises the steps of providing a glass tube with an annular passage, forming a preform from the glass tube while maintaining the annular passage, and drawing the preform into the glass article such that the annular passage closes during drawing. The preform is formed by the steps of providing glass on an inner surface of the glass tube while maintaining the annular passage and providing glass on an outer surface of the glass tube. The preform has a predetermined value α that is an inner diameter of the preform after providing glass on the inner surface divided by an outer diameter of the glass tube. The preform has a predetermined value β that is the inner diameter of the preform after providing glass on the inner surface divided by the outer diameter of the preform.

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METHOD OF MANUFACTURING AN OPTICAL FIBER FROM A PERFORM AND OPTICAL FIBER MADE BY THE METHOD

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application, Serial Number 60/295,107, filed May 31, 2001 entitled METHOD OF FORMING A GLASS ARTICLE BY COLLAPSING AN ANNULAR PASSAGE OF A PREFPRM DURING DRAW, by Julie E. Caplen, Daniel W. Hawtof, and Jean P. deSandro.

BACKGROUND OF THE INVENTION

Field of the Invention

[0002] The invention relates generally to a method of manufacturing a glass article and, more particularly, to a method of manufacturing an optical fiber by drawing a preform while closing an annular passage in the preform.

Description of the Related Art

[0003] An optical fiber is typically manufactured by forming an optical fiber preform and drawing an optical fiber from the preform. Conventional processes for forming the preform include chemical vapor deposition (CVD) processes, such as outside vapor deposition (OVD), vapor axial deposition (VAD), modified chemical vapor deposition (MCVD), and plasma activated chemical vapor deposition (PCVD).

[0004] In typical MCVD and PCVD processes, a preform is formed by depositing glass on the inner surface of a glass tube. The deposited glass provides the material that ultimately forms the core and a portion of the cladding of the optical fiber. The glass tube provides the material that ultimately forms at least a portion of the cladding of the optical fiber.

[0005] In the MCVD process, for example, layers of doped silica are deposited onto the inner surface of the glass tube. The doped silica is deposited in thin layers of soot through a vapor deposition technique. As the soot is being deposited, it is sintered into glass by, for example, an oxygen-hydrogen torch heating the outside

[0010] It is expected that the non-symmetrical layers of glass 14 in the preform 10 will result in asymmetry in an optical fiber drawn from the preform 10. Additionally, it is expected that the asymmetry will be present, in varying magnitudes and shapes, along the length of the preform 10 (and the resulting optical fiber).

[0011] An asymmetric profile can cause variations in the core diameter along the length of the fiber core so that transmitted light "sees" a different core cross-sectional area at different points along the length of the optical fiber. In addition, an asymmetric profile can reduce the bandwidth of laser launched multimode fibers.

[0012] An asymmetric profile is also believed to be one of the main causes of polarization mode dispersion (PMD). PMD is a form of dispersion which results when one orthogonal component of light travels faster than another orthogonal component. The two components of light; electric and magnetic, are sinusoidal. PMD is a severe problem when it is present to any significant degree in single mode fibers, for at least the reason that it limits the rate of data transmission in fiber-based telecommunications systems.

[0013] More specifically, single mode fibers and multimode fibers both have an outside diameter of generally about 125 microns. However, single mode fibers have a smaller core diameter, e.g., about 8 microns. This dimensional relationship makes single mode fibers extremely sensitive to PMD. Consequently, eliminating PMD is a significant goal in fiber manufacturing, especially in single mode fibers.

[0014] In contrast to the small core size of single mode fibers, the core region of a multimode fiber commonly has a diameter of 50 or 62.5 microns. In multimode fibers, non-symmetric closure of the annular passage has resulted in the inability to tune refractive index profiles in the inner-most portion of the fiber adjacent the centerline. As a result, lasers used to launch light into such fibers are often offset some distance from the centerline of the multimode fiber to avoid this region of non-symmetric hole closure.

[0015] The spinning of an optical fiber during draw operation is one way to reduce PMD. Spinning involves a process where the fiber is mechanically twisted along its

the preform after providing glass on the outer surface. The preform is drawn to form an optical fiber while closing the annular passage.

[0019] Yet another aspect of the present invention relates to a method of manufacturing an optical fiber. The method comprises the steps of providing a glass tube with an annular passage, and forming a preform by the steps of providing glass on at least an inner surface of the glass tube while maintaining the annular passage to provide the preform having a predetermined value β that is the diameter of the annular passage divided by the outer diameter of the preform. The preform is drawn to form an optical fiber while closing the annular passage.

[0020] A further aspect of the present invention relates to a glass article, such as an optical fiber, made in accordance with the disclosed methods.

[0021] It is to be understood that the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the invention, as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] The accompanying drawings, which are incorporated in and constitute part of this specification, illustrate an embodiment of the invention and together with the description, serve to explain the principles of the invention.

[0023] Fig. 1 is a drawing, based on data, of an expected cross-sectional profile of a preform formed using a conventional process and an expected cross-sectional profile of an optical fiber formed from the preform;

[0024] Fig. 2 is a drawing, based on data, of an expected cross-sectional profile of an optical fiber formed in accordance with the present invention;

[0025] Fig. 3 is a cross-sectional view of a glass tube with glass deposited thereon;

[0026] Fig. 4 is a side view of a preform disposed above a draw furnace with a sealed annular passage.

and sintering the soot particles (e.g., a MCVD process). Alternatively, the glass 51 can be provided on the inner surface 52 by depositing glass particles on the inner surface (e.g., a PCVD process). As another alternative, the glass 51 can be provided by a sleeving technique. In this technique, a glass sleeve or tube (not shown) having an outer diameter slightly less than the inner diameter of glass tube 50 can be inserted into the glass tube 50. Other conventional processes could be used to provide glass 51 on the inner surface 52.

[0033] The glass 51 provides a first predetermined value α, which is a diameter of the annular passage 60 after glass 51 has been provided on the inner surface 52 divided by the outer diameter of the glass tube 50. The first predetermined value α is, in the case of depositing soot, determined after the soot has been sintered. The first predetermined value α preferably is at least approximately 0.7, more preferably is at least approximately 0.725, and even more preferably is at least approximately 0.75. Additionally, the first predetermined value α preferably is no more than approximately 0.9, more preferably is no more than approximately 0.875, and even more preferably is no more than approximately 0.85. After the addition of glass 51, the diameter of the annular passage 60 preferably is at least 2 millimeters smaller than the original inner diameter of tube 50. The preferred diameter of the annular passage 60 is in the range of approximately 10 to approximately 33 millimeters, more preferably approximately 19 to approximately 23 millimeters, and most preferably approximately 17 to approximately 21 millimeters. The glass 51 preferably has a mass per unit length of approximately 5 to approximately 100 grams per meter. For example, a PCVD process normally deposits about 120 grams on a 21 mm ID by 25 mm OD tube, about 8 grams of which is core material and the rest is clad material.

[0034] Next, glass 53 is preferably provided on the outer surface 54 of the glass tube 50 to increase the outer diameter. The glass 53 can be provided on the outer surface 54 by conventional techniques, such as depositing soot particles on the outer surface and sintering the soot particles, depositing glass particles on the outer surface, or a sleeving technique. As particular examples, conventional techniques

[0038] The soot particles preferably are dried after deposition on the glass tube 50. For example, the soot particles can be dried in an atmosphere containing a chlorine drying gas. A preferred drying atmosphere contains up to two (2) percent Cl_2 and an inert gas. Preferably, the temperature of the drying atmosphere is between about 800 to about 1100°C. The drying step preferably lasts from about thirty (30) minutes to about four (4) hours, more preferably about two (2) hours. The particles can be dried before being placed in the draw furnace 74 or they can be dried in the draw furnace 74. When the soot particles are dried in the draw furnace 74, the drying step can be concluded with an inert gas purge of the draw furnace 74. Preferred purge gases include helium, nitrogen, argon, or mixtures thereof. However, any known inert gas may be used as the purge gas.

[0039] After drying, the soot particles are sintered into a dense glass by heating them to a temperature of no more than about 1700 °C, preferably about 1400 to about 1500 °C, and more preferably about 1450 °C. The sintering step preferably lasts about 1 to about 6 hours, more preferably 2 to 4 hours. The atmosphere during sintering typically is also an inert atmosphere, where any conventional inert gas or mixture of gases including noble gases and nitrogen may be used. Preferably, helium is used as the sintering atmosphere. As with drying, the soot particles can be sintered before being placed in the draw furnace 74 or they can be sintered in the draw furnace 74.

[0040] The draw furnace 74 is provided, preferably in a vertical orientation, for drawing the glass preform 70 into a glass article, e.g., an optical fiber, while closing the annular passage 60. As shown in Fig. 4, the preform 70 is suspended by integral handle 58 on downfeed handle 72. The furnace 74 preferably employs a heat source (not shown) that is symmetric about the periphery of the preform 70. For example, in a preferred embodiment, the heat source is a vertically oriented cylindrical furnace having gradient heat zones. One such furnace employs heat zones of increasing temperature from top to bottom. Consequently, as the preform 70 is inserted into the top of the furnace and lowered into it, the annular passage 60 will close from the bottom.

handle 58 could be rotated with respect to inner handle 76. Further, both inner handle 76 and integral handle 58 could be rotated with respect to one another.

[0044] After snapping bent tab 68 from preform 70, a dry or drying gas is continuously passed into inner handle 76 thereby maintaining interior cavity 71 of inner handle 76, the interior cavity 69 of integral handle 58, and annular passage 60 of preform 70 free of contaminants and from being recontaminated. A valve 82 controls the flow of gas from the gas supply 84 and whether the gas is directed directly to interior cavity 71 of inner handle 76 or vented to an exhaust tube 86. Exhaust tube 86 is coupled with a one-way valve 88 that prevents the entry of air into exhaust tube 86 and the contamination of annular passage 60 of preform 70 by ambient air and the contaminant matter associated therewith. One-way valve 88 may be provided in the form of a bubbler, a check valve, or any other form of a one-way valve that prevents the backflow of ambient air into exhaust tube 86. Alternatively, exhaust tube 86 may be provided at such a substantial length that backflow of ambient air into exhaust tube 86 is prevented from reaching annular passage 60 of preform 70.

[0045] After the annular passage 60 of the preform 70 has been opened and purged, the preform 70 is lowered further into the hot zone of furnace 74 and/or the temperature is increased to a temperature sufficient to allow an optical fiber to be drawn from the preform 70. The temperature in the furnace 74 during draw is preferably in the range of approximately 1800 to approximately 2100 °C, and more preferably approximately 1900 to approximately 2000 °C. The preform 70 is preferably heated at a rate of at least approximately 20 °C per minute.

[0046] While preform 70 is being heated with furnace 74, a gob or sphere of molten glass (not shown) will begin to collect at the bottom end of the preform 70. If the annular passage 60 is constantly purged while the preform is heated within the hot zone, it may be necessary to decrease or eliminate the purge pressure of the dry or drying gas to prevent the enlargement and or rupture of the glass sphere. Allowing the glass sphere to rupture may allow the dry or drying gas to exit the preform 70 and hinder the closure of annular passage 60 and the formation of the optical fiber

between about 761.8 and 769 Torr, more preferably about 764.4 Torr, where atmospheric pressure is assumed to be equal to 760 Torr) such as that caused by the purge pressure of the gas or drying gas entering annular passage 60. In this way, annular passage 60 can be maintained under pressure during the fiber drawing step which is sufficient to result in a circular geometry. Preferably, the surface tension at the point at which the annular passage closes is greater than a vacuum force at that point. The appropriate pressure will depend on other factors, such as draw speed, blank size, and draw temperature.

[0049] Fig. 2 shows the expected cross-sectional profile of an optical fiber 20 formed in accordance with the present invention. Notice the circular symmetry of the layers of glass 24 about the centerline 22. The symmetry shown decreases the PMD in optical fibers to below maximum acceptable levels for a given system. It is expected that the symmetry seen here will be present in the optical fiber drawn from the preform and will be consistent throughout the entire length of the optical fiber.

[0050] As mentioned above, the preform 70 should be structured such that the outer diameter of the preform 70 is sufficiently large with respect to the diameter of the annular passage 60 so that the forces internal to the preform 70 generated by reduction of the outside diameter cause the annular passage 60 to close. In other words, the predetermined value β should be selected to cause closure of the annular passage through surface tension and/or capillary forces, without the need for external forces, such as vacuum forces.

[0051] The preform 70 can be formed with the predetermined value β using techniques different from the technique described above. For example, glass 53 can be provided on the outer surface 54 of the glass tube 50 before glass 51 is provided on the inner surface 52. Alternatively, the initial configuration of the glass tube 50 can be such that glass need only be provided on the inner surface 52 to achieve the desired predetermined value β.

Using the methods disclosed herein, optical fibers can be achieved which have an outside diameter of 125 microns, yet the layers of glass surrounding the

What is claimed is:

1. A method of manufacturing an optical fiber, comprising the steps of: providing a glass tube with an annular passage;

forming a preform by the steps of:

providing glass on an inner surface of the glass tube while maintaining the annular passage,

providing glass on an outer surface of the glass tube,

wherein the preform has a first predetermined value α that is a diameter of the annular passage after providing glass on the inner surface divided by an outer diameter of the glass tube, and the preform has a second predetermined value β that is the diameter of the annular passage after providing glass on the inner surface divided by an outer diameter of the preform after providing glass on the outer surface; and

drawing the preform into an optical fiber such that the annular passage closes during drawing.

2. The method of claim 1, wherein at least one end of the annular passage of the preform is open during drawing.

3. The method of claim 1, wherein the drawing step causes the annular passage to close substantially uniformly in the radial direction.

4. The method of claim 1, further comprising the step of exposing the annular passage to gas during drawing.

5. The method of claim 4, wherein a pressure of the gas in the annular passage is at least 500 Torr.

6. The method of claim 1, wherein the first predetermined value α is at least approximately 0.7.

surface divided by an outer diameter of the preform after providing glass on the outer surface; and

drawing the preform into a glass article such that the annular passage closes during drawing.

14. The method of claim 13, wherein the first predetermined value α is in the range of approximately 0.7 to approximately 0.9.

15. The method of claim 13, wherein the second predetermined value β is in the range of approximately 0.1 to approximately 0.4.

16. The method of manufacturing an optical fiber, comprising the steps of:

providing a glass tube with an annular passage;

forming a preform by the steps of:

providing glass on at least an inner surface of the glass tube while maintaining the annular passage to provide the preform having a predetermined value β that is the diameter of the annular passage divided by the outer diameter of the preform; and

drawing the preform into an optical fiber such that the annular passage closes during drawing.

17. The method of claim 16, wherein the predetermined value β is in the range of approximately 0.1 to approximately 0.4.

18. An optical fiber made by the method of claim 1.

19. An optical fiber made by the method of claim 16.

20. The optical fiber of claim 18, wherein said fiber is comprised of:

concentric layers of glass; and any glass layer between about .08 to about .15 microns from the centerline exhibits a change in radial dimension around its periphery which is less than .025 microns.

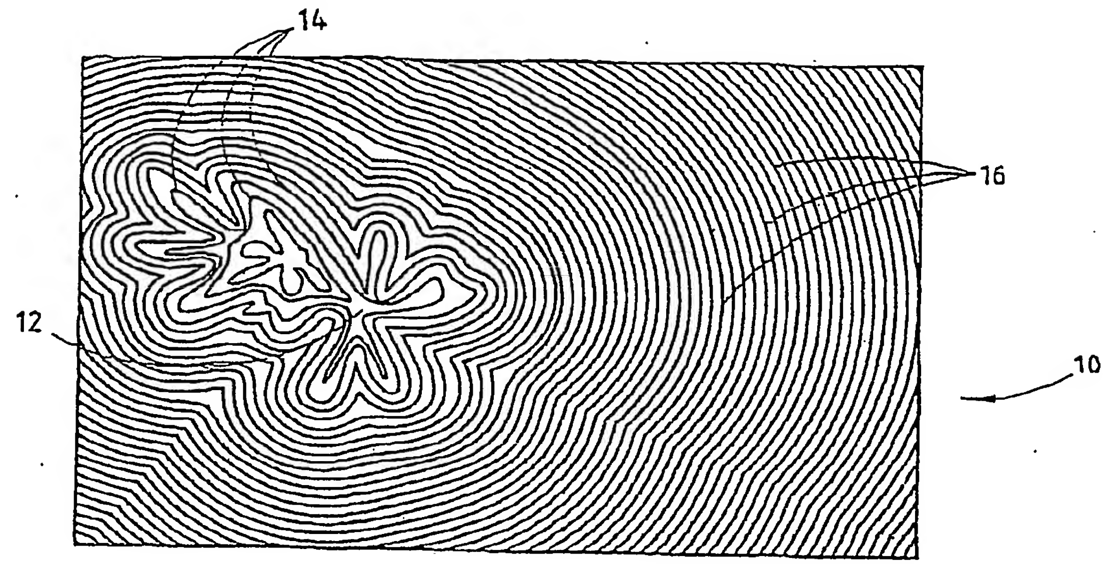

FIG. 1

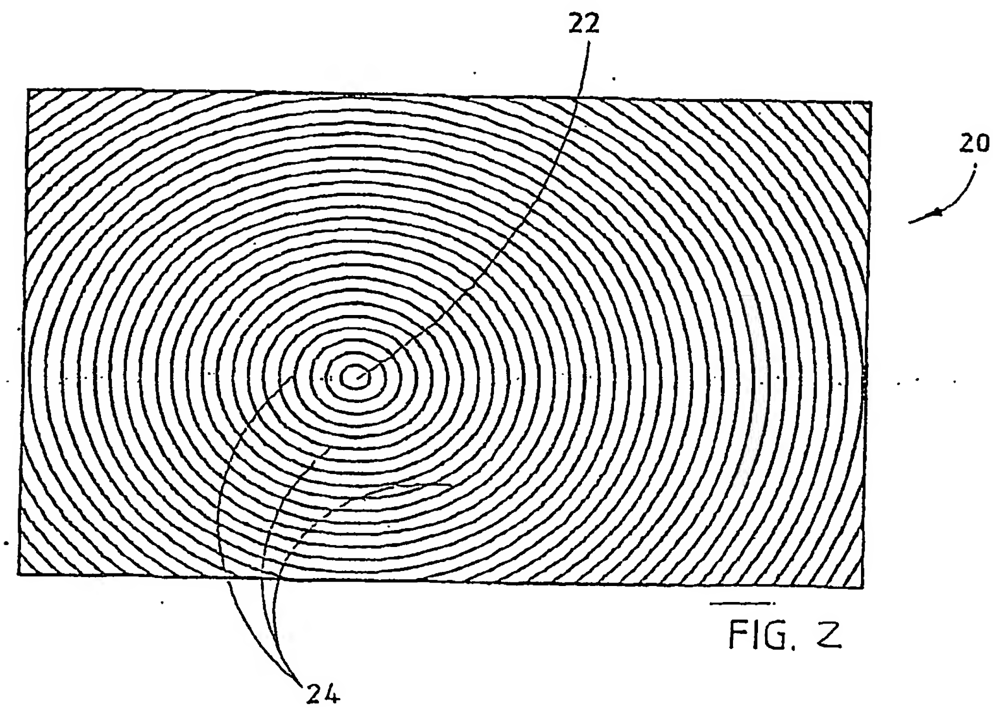

FIG. 2

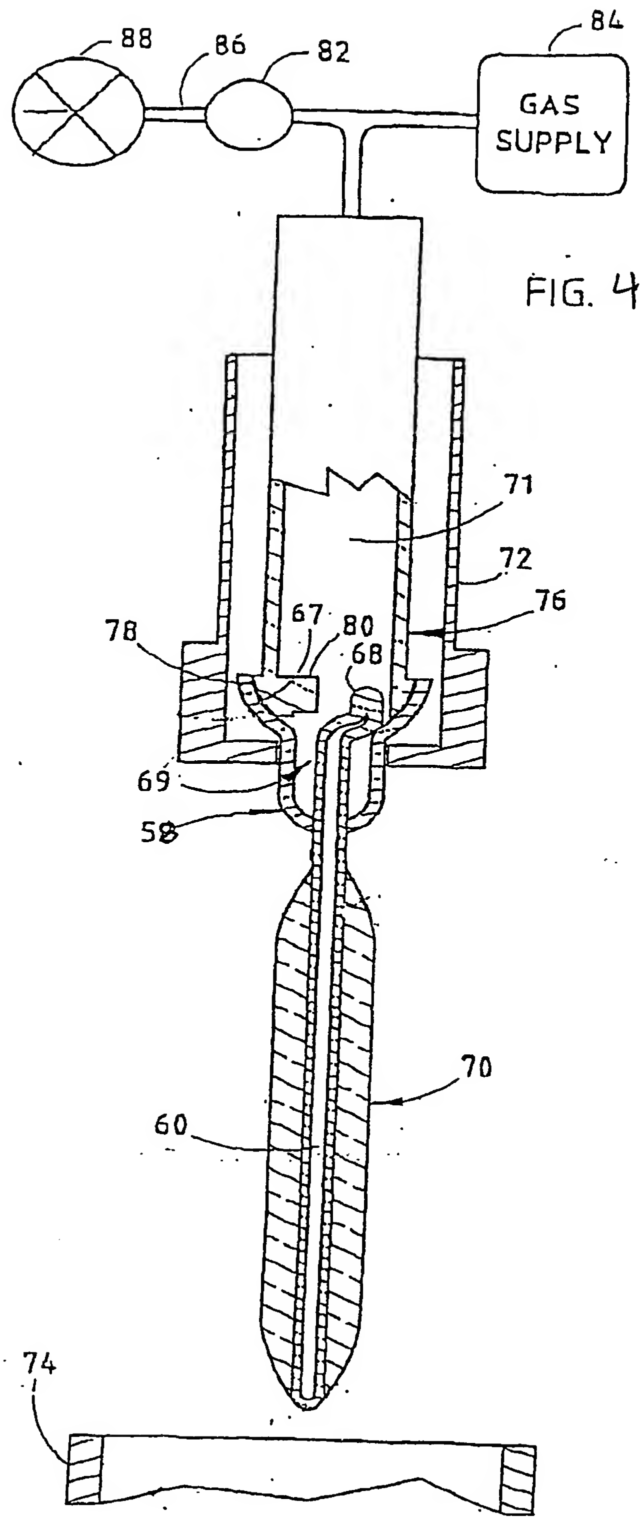

FIG. 4

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 02/10974

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 C03B37/018 C03B37/014 C03B37/027

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 C03B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	US 4 123 483 A (NAKAHARA T ET AL) 31 October 1978 (1978-10-31) the whole document	1,13,16, 18,19

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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Date of the actual completion of the international search	Date of mailing of the international search report
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Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

Information on patent family members

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